HYDROGEN MICROSENSOR BASED ON NiO

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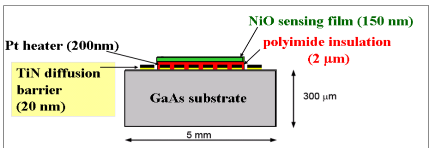
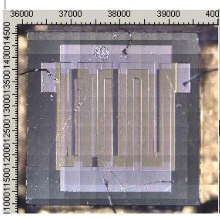
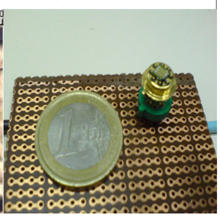
Abstract. A multitude of industries use H_2 either as part of their process or as a fuel. All these applications motivate the development of hydrogen sensor devices which enable its safe and controlled use. Since H_2 is explosive above the lower explosion limit at 40000 ppm, devices which permit the detection of its presence and measure its concentration become indispensable. In this work, we present a microsensor based on NiO thin films produced with dc reactive magnetron sputtering on GaAs, with an incorporated Pt heater, all on a DO-8 package and ready for use. The microsensor was tested to H_2 concentrations 5000 and 10000 ppm at different working temperatures. The change of the electrical resistance of NiO thin films was the signal for hydrogen sensing. The response of the sensor was not proportional to concentration of the gas neither to working the temperature.

Development and Structure of the microsensor

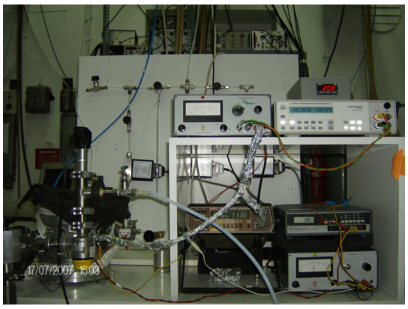


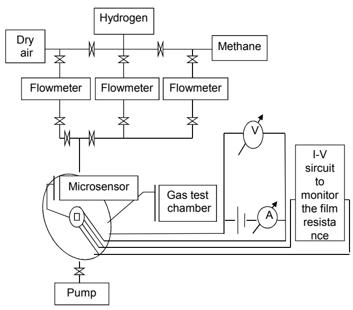




- The different layers of the microsensor were deposited by dc reactive magnetron sputtering on a GaAs substrate
- By using a suitable mask and a photolithographic process, platinum integrated heater having a shape of meander was realized.
- A layer of polyimide was deposited on Pt heater for electrical isolation.
- At the top NiO (p-type semiconductor) thin films were deposited.
- The microsensor was placed on a DO-8 package with necessary electrical connections ready for use.

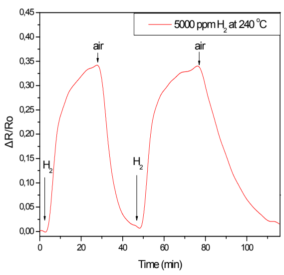
Experimental Set up

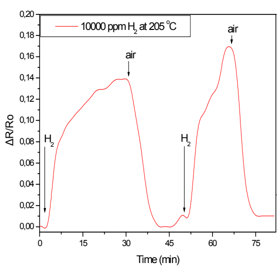


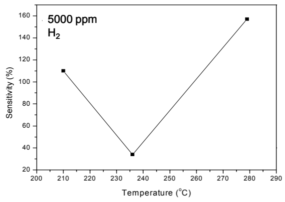


- The sample was mounted inside a gas test chamber which was evacuated to 10^{-2} mbar.
- The chamber was filled with dry air and then heated at various temperatures.
- Using an electrometer the resistance change of the NiO film was monitored in real time.
- Measuring the Pt heater's resistance the temperature of the microsensor was known
- Flowmeters was used to measure the flow

Results







- The microsensor was tested at 5000 ppm (working temperatures 210, 240 and 280 °C) and 10000 ppm (working temperatures 185 and 205 °C) of H_2.
- The concentration of hydrogen was calculated using the partial pressures of the sensing gas and air in the chamber.
- The change of the electrical resistance of NiO thin films was the signal for hydrogen sensing.
- The response of the sensor was not proportional to the concentration of the gas neither to the working temperature.

Sensing Mechanism

- The electrical resistance of NiO increased considering that NiO is a p-type semiconductor and hydrogen is a reducing gas.
- The NiO p-type conductivity is due to the non-stoichiometry of the prepared samples, in which vacancies occur in cation sites (metal deficiency).
- Atmospheric oxygen is expected to be chemisorbed on the surface of NiO as O_2,ads− and Oads− negative charged chemical species.
- The high coverage with chemically bound oxygen species causes an increase in the concentration of the holes of the NiO film and an increase in its conductivity.
- The presence of H_2 causes a decrease of the electrical conductivity, because H_2 reacts with adsorbed oxygen and forms water vapor, injecting electrons back in the NiO p-type semiconducting film that recombine with holes:

$$2H_{2,gas} + O_{2,ads}^{-} \leftrightarrow 2H_2O_{vap} + e^{-}$$

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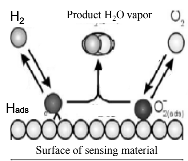

Future Plans

- One future plan is try to detect hydrogen at lower concentrations.
- Try to detect hydrocarbons and especially methane as it is the highest concentration ingredient of the natural gas.
- Try to improve the response time, increase the sensitivity, improve the selectivity and lower the working temperatures close to RT by depositing metallic clusters (Pt, Pd, Au etc) on the surface of the sensor.

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